# DENSITY AND NATURAL REGENERATION POTENTIAL OF SELECTED NON-TIMBER FOREST PRODUCTS SPECIES IN THE SEMI-DECIDUOUS RAINFOREST OF SOUTHEASTERN CAMEROON

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ABSTRACT This study was conducted to determine the population structure and the status of natural regeneration for eight edible and/or commercial wild fruit tree species (*Afrostyrax lepidophyllus*, *Baillonella toxisperma*, *Irvingia gabonensis*, *Panda oleosa*, *Pentaclethra macrophylla*, *Ricinodendron heudelotii*, *Scorodophloeus zenkeri* and *Tetrapleura tetraptera*) in semi-deciduous rainforest of southeastern Cameroon. We established 16 transects with 5 km in length and 20 m in width each. Along each transect, all individuals, from seedlings to mature trees, of the eight species were recorded and their diameter at breast height (DBH) was measured. The results show high density values for *Afrostyrax lepidophyllus* (32.0 ± SD 26.1 stems/ha), *Ricinodendron heudelotii* (10.3 ± 18.5 stems/ha), *Pentaclethra macrophylla* (11.3 ± 8.2 stems/ha) and *Scorodophloeus zenkeri* (7.4 ± 12.8 stems/ha). The lowest density was reported for *Baillonella toxisperma* (0.1 ± 0.1 stems/ha). The investigated species have numerous seedlings, saplings and young trees, except *Baillonella toxisperma*, *Irvingia gabonensis*, *Panda oleosa* and *Tetrapleura tetraptera* (0.04, 1.05, 0.51 and 0.37 individuals of DBH < 5 cm per ha, respectively). They have relatively low natural regeneration index and are considered of priority for conservation in this forest. The study demonstrates the need to intensify the domestication or assisted natural regeneration of these wild fruit trees in degraded areas and to develop innovative approaches to multiple-use forestry, which could include NTFPs, timber and environmental services.

Key Words: Population structure; Natural regeneration; NTFP; Conservation.

## INTRODUCTION

The Central Africa region is endowed with a great diversity of flora and fauna. The heart of this region, the Congo Basin, has the second largest contiguous rainforest in the world after the Amazon Basin. Cameroon is part of this Congo Basin. It has 22.5 million hectares of forest, which cover 48% of the land base (de Wasseige et al, 2009). These forests are home to a wide variety of fauna, including 250 species of mammals, 542 fishes, 848 birds, 330 reptiles, and 200 amphibians (Fomété & Tchanou, 1998). The country's flora is estimated to comprise about 10,000 species, of which 7,850 have already been documented at the national herbarium of Cameroon (Onana, 2011). Most of the country's biodiversity is located in forested areas and the lower Guinean forest, which is renowned for its high number of endemic plant and animal species (Devers & van de Weghe, 2007). This richness in plant diversity provides timber and Non-Timber Forest Products (NTFPs) that contribute to the national economy and support the lives of millions of rural and urban citizens. NTFPs, as defined by the United Nations Food and Agricultural Organization, are "goods of biological origin other than wood derived from forests, other wooded lands and trees outside forests" (FAO, 1999). NTFPs provide people with foods, medicinal plants, ornamental plants, energy, building materials, fishing equipment, and various other goods and have great socio-cultural and religious values. About 80 percent of the population of central Africa depends on NTFPs to meet their daily needs, including income and employment (Walter & Malele Mbala, 2006).

The past decade has witnessed a rapid increase of interest in NTFPs. Conservation and development organizations have demonstrated that NTFPs contribute to rural livelihoods, thereby providing an incentive for the conservation of forests (van Rijsoort, 2000; Marshall et al., 2003). Many studies have documented the utilization of NTFPs and their impacts on poverty reduction, livelihood improvement and environmental sustainability in Cameroon (Doucet & Koufani, 1997; Ndoye et al., 1997; Tabuna, 1999; Fankap et al., 2001; Mbolo, 2002; Vermeulen & Doucet, 2004; Tchatat & Ndoye, 2006; Manirakiza, 2007; Awono et al., 2009; Lescuyer, 2010). Peters et al. (1989) estimated that the long-term economic returns from tropical forests managed for NTFPs are greater than the net returns from timber or forest conversion to agriculture. Many studies showed that harvesting NTFPs has a low impact on forest ecosystem, which complies with forest conservation objectives (van Dijk, 1999; Wong et al., 2001). With regards to climate change mitigation, some studies have recently noted that the utilization of NTFPs is compatible with the $REDD^+$ mechanism for "reducing emissions from deforestation and forest degradation including conservation, sustainable management of forest and enhancement of forest carbon stock." Thus, promoting NTFPs which are deforestation-free commodities are an additional market-based approach to conservation (Peña, 2010).

However, many studies of NTFPs have concentrated more on socio-economic issues than their biology. Because of their importance to local livelihoods and biodiversity conservation, there is a need to accurately quantify the availability of NTFPs in terms of growing stock and yields. The identification of sustainable harvesting options is also critical (Wong et al., 2001; Ojha & Bhattarai, 2003). As suggested by Peters (1994), a process for utilizing NTFPs should begin with the selection of species or products, including market research, an inventory of the resource, the assessment of growth and yield predictions, the determination of sustainable harvest levels, management planning and monitoring. Resource inventories can be used to estimate the potential of particular products for which increased commercialization is sought, or to provide supporting data for the determination of quotas, especially for products, such as bark of *Prunus africana* (Red stinkwood) from Cameroon, that are subject to national legislation or international treaties (e.g., the Convention on International Trade of Endangered plant and animal Species – CITES) (Ingram et al., 2009).

Sustainable management of natural forests depends on their ability to regenerate. In this respect, understanding natural regeneration processes and the distribution of recruits is of paramount importance to estimating the future forest structure and composition (Tesfaye et al., 2002; Ceccon et al., 2006) and to create or enforce conservation regulations (Schaafsma et al., 2011). The regeneration status/potential of a species can be assessed from the population dynamics of seedlings and saplings in the forest community (Duchok et al., 2005). Several studies have predicted the regeneration status of tree species based on the age and diameter structure of their populations (Pritts & Hancock, 1983; Bhuyan et al., 2003). A population structure characterized by the presence of sufficient number of seedlings, saplings and young trees exhibits satisfactory regeneration potential, while an inadequate number of seedlings and saplings is indicative of poor regeneration potential (Saxena & Singh, 1984).

In Cameroon, only a few quantitative ecological assessments of NTFPs have been performed (van Dijk, 1999; Zapfack & Ngobo, 2001a; 2001b; Guedje, 2002; Fongnzossie, 2003; Fokou-Sakam, 2008; Nnanga et al., 2012; Ndah et al., 2013). Most of these studies reported low densities for most NTFP species, especially those used as commercial timber species, within natural forests. Similar observations were obtained from a NTFP survey conducted by the Organization for Environment and Sustainable Development in 48 rainforest communities in South Cameroon (Fongnzossie et al., 2009). All of these studies recommended the domestication of NTFP species to allow their management in anthropogenic land use types. They also suggested that the development of silvicultural enhancements of selected NTFP species is a promising option to sustainably raise farmers' incomes. Similarly, a NTFP expert meeting held in Limbe in 1998 mentioned the need for ecological research of NTFPs to be made available to local communities, other resource users and decision-makers for the full value of the forest to be reflected in forest use decisions (Sunderland et al., 1998).

Despite these warnings, country- or region-wide quantitative ecological data on NTFPs are scarce. There is a lack of scientific evidence on the impact of fruit gathering on the regeneration of most NTFP species. The lack of data on densities, yields, and annual increments of harvestable stock makes it impossible to be confident about the sustainability of future supplies. Moreover, for commercial species, the delivery of harvesting licenses, as well as the determination of harvest quotas, as provided by Cameroon's forest law, are not based on knowledge of the availability, distributions, yields or natural regeneration capacities of wild populations (SNV, 2004). Thus, it is likely that some NTFP species are not being harvested sustainably.

As Cameroon's forest law is currently being revised, there has been a growing demand for NTFP species inventory data from forestry professionals to support decision-making. This research is a case study of eight tree species whose fruits are widely used as subsistence foods and/or important cash income sources by people in the study area (Gribe village, southeastern Cameroon). The eight species are: *Afrostyrax lepidophyllus*, *Baillonella toxisperma*, *Irvingia gabonensis*, *Panda oleosa*, *Pentaclethra macrophylla*, *Ricinodendron heudelotii*, *Scorodophloeus zenkeri* and *Tetrapleura tetraptera*. The primary objective was to determine the population structure and the status of natural regeneration of these species. The study seeks to answer the following questions:

- What is the growing stock of these NTFP species in resource use zones of Gribe forests?
- What is the current status of natural regeneration of their populations?
- To what extent could growing stocks sustain the NTFP supply for local people?

The study also discusses the implications of the findings for conservation and sustainable management of these NTFPs.

## STUDY AREA

This study was conducted in southeastern Cameroon in Gribe village located at 03°00'10'' N and 14°49'25'' E, at the northern periphery of Boumba-Bek National Park (Fig. 1). This park is part of the Tri-national Dja-Odzala-Minkébé landscape also called TRIDOM, a transnational conservation complex comprised of Odzala-Koukoua National Park (Congo), Minkébé National Park, Ivindo National Park and Mwagna National Park (Gabon), Dja Fauna Reserve, Mengame Gorilla Sanctuary, Boumba-Bek, Nki and Kom National Parks (Cameroon). As described

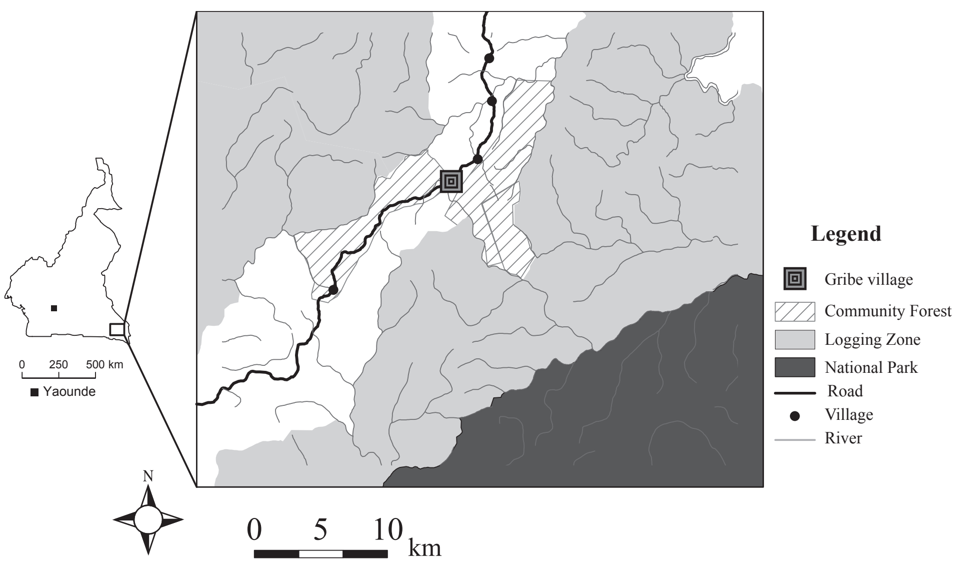


**Fig. 1.** Location of the study area.

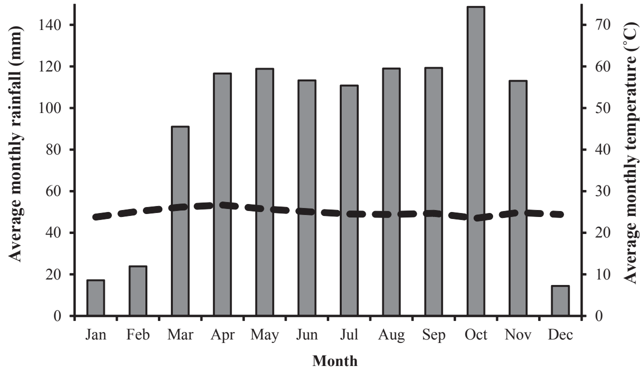


**Fig. 2.** Monthly temperature and precipitation in the study area.

by Letouzey (1985), the vegetation of this region is semi-deciduous forest mostly comprising Sterculiaceae (e.g., *Triplochiton scleroxylon*, *Cola* spp., *Mansonia altissima*, *Nesogordonia papaverifera*, *Pterygota macrocarpa* and *Sterculia* spp.) and Ulmaceae (e.g., *Celtis* spp. and *Trema orientalis*). Previous mapping and profiling of the vegetation in Boumba-Bek National Park (Nkongmeneck, 1999) identified 390 plant species and a great diversity of habitat types. These include dry and wet savannahs dominated by shrubs like *Dichrostachys cinerea*, *limbali* (*Gilbertiodendron* monodominant forest), gallery forests, dry and wet grasslands, swamp forest dominated by *Alstonia congensis*, *Hallea ciliata*, *Uapaca* spp. and *Lemna paucicostata*, *Raphia* forest, *Mapania* forest with high liana densities, open canopies and very thick understories, Marantaceae forest and *Baphia leptobotrys* forest.

The local population consists of two ethnic groups: the Baka hunter-gatherers and the Konabembe Bantu-speaking agriculturalists. Their livelihoods are dependent upon farming, hunting, gathering, cacao cultivation and NTFPs.

Annual rainfall varies from 1300 to 1600 mm (Sigha-Nkamdjou, 1994) and the average temperature is 25°C (Fig. 2). The area is subject to a Guinean equatorial climate with four seasons divided as follows:

- a major dry season from December to mid-March;
- a minor rainy season from mid-March to June;
- a minor dry season in July and August;
- a major rainy season from late August to November.

## METHODS

### I. Species Selection

Identification of the most economically important NTFPs was attained through participatory survey with the local population. The following eight species were selected based on their high frequency of utilization and commercialization at the village level (Hirai, 2014, this issue). Among them, *Baillonella toxisperma*, *Ricinodendron heudelotii* and *Irvingia gabonensis* are listed among the key NTFP species of Central Africa (Clark & Sunderland, 2004):

1. *Afrostyrax lepidophyllus* is a rare species with a disjunct distribution. According to the International Union for Conservation of Nature (IUCN) red-list of threatened species, subpopulations of this species have significantly declined, what justifies its presence in the "Vulnerable" category (Hawthorme, 1998).
2. *Baillonella toxisperma* is a large, lowland rain forest species that is only found from southeastern Nigeria to the Democratic Republic of the Congo. It is a valuable timber species that also is prized for the distinctive oil that is obtained from its fruits. Local people also use other parts of the tree for medicines. Fruits of *B. toxisperma* are known to be dispersed by several different animals (Schneemann, 1995). The species is currently listed in the "Vulnerable A1cd" category of the IUCN red-list (IUCN, 2013). It was reported to be overexploited for its timber and is in serious decline in large parts of its range (White, 1998). In Cameroon, because of the threat of extinction, *B. toxisperma* is now under protection by the Ministry of Forests and Wildlife.
3. *Irvingia gabonensis* is indigenous to the humid forest zone of the Gulf of Guinea from western Nigeria east to the Central African Republic, and south to Cabinda (Angola) and the westernmost part of the Democratic Republic of the Congo. The species is currently listed in the "Lower Risk/near threatened" category of the IUCN red-list (IUCN, 2013).
4. *Panda oleosa* occurs from Liberia east to the Central African Republic and the Democratic Republic of the Congo. It is usually an understorey tree in evergreen to semi-deciduous primary forest and thrives on both swampy and dry sites. It can also be found in riverine and periodically flooded forest. Its seeds germinate slowly, starting after 10 months to 4 years. In general, seedlings are not common in the forest, although older trees are reported to be clustered in many areas.
5. *Pentaclethra macrophylla* occurs in the forest zone of West and Central Africa. It is common in primary and secondary forest.
6. *Ricinodendron heudelotii* is a fast-growing tree that often occurs in young secondary forest in the Guinean-Congolean humid forests of West and Central Africa. It is valued for its distinctively flavored seeds, most commonly called "*njansang*" in Cameroon, which are dried and ground and used as flavorings and thickening agents in food (Tchoundjeu & Atangana, 2006). Fruits are produced in large quantities, and most of them remain dormant for about 6 months. They are said to be dispersed by bats, hornbills and rodents.
7. *Scorodophloeus zenkeri* is an evergreen forest species found in tropical Africa from Nigeria to the Democratic Republic of the Congo.
8. *Tetrapleura tetraptera* is widespread in tropical Africa rainforest, especially secondary forest, in riverine forest and savannah woodland (Orwa et al., 2009). *T. tetraptera* is one of the most valued forest species in Central Africa. The fruits and seeds add aroma and flavor to food. In addition, the species has many medicinal uses (Omokhua & Ukoimah, 2008).

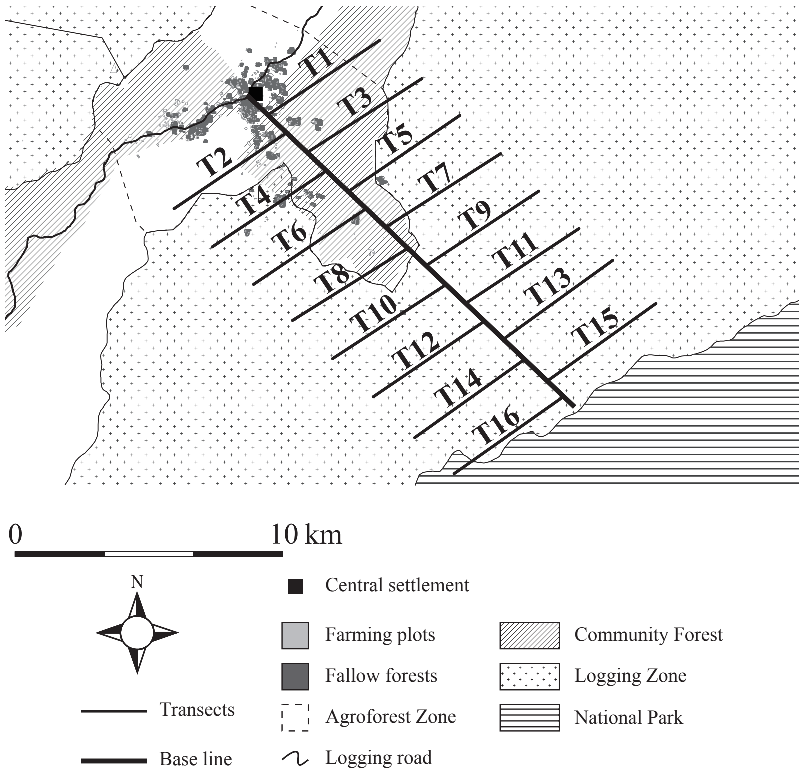


**Fig. 3.** Schematic of the sampling design used in this study.

## II. Data Collection

NTFP species inventory approaches are often based on conventional forestry methods, i.e., sample plots, and transect sampling technique. In scattered populations, plot sampling typically encounters only a few specimens of interest. Because plants often have a very patchy distribution, the ability to cover a large area of ground with modest resources is an important advantage of line transects. We used a sampling design consisting of an approximately 16 km baseline (oriented SE-NW) and 16 transects of 5 km (oriented SW-NE). Sampling was performed within 10 m on both sides of the transects. Thus, the sampled area of each transect was 10 ha. Along each transect, all individuals, from seedlings to adult individuals, of each species were recorded and their DBH was measured. The distance between consecutive transects was 1 km (Fig. 3). The total area sampled was 160 ha.

III. Data Analysis

The total counts for the studied NTFPs were analyzed by species, transect, and diameter class. Tree density was calculated and scaled up to transect diameter-class or whole study area levels using an expansion factor. The size-class distribution of the target species was used to characterize population structures.

To determine and compare the natural regeneration potentials of each species, we calculated a natural regeneration index (NRI), adapted from Hakizimana et al. (2011), based on the ratio between the number of individuals with 0 < DBH < 5 cm and the number of individuals with DBH ≥ 5 cm. A species was considered to have good regeneration when NRI ≥ 1. According to Hakizimana et al. (2011), this threshold value of 1 was chosen because the number of adult individuals in a population is expected to be equal to or greater than the number of young individuals in a normal regeneration situation of a population, (Fargeot et al., 2004).

Analysis of variance (ANOVA) was performed to examine whether NTFP densities varied according to species, and the Spearman correlation analysis was used to examine the relation between distance from the village and seedling density and natural regeneration index of the species.

RESULTS

I. Population Density and Structure

The population census of the eight species showed the greatest density values for *Afrostyrax lepidophyllus* (mean density and the standard deviation was 32.0 ± 26.1 stems/ha). *Baillonnella toxisperma* (0.1 ± 0.1 stems/ha) and *Tetrapleura tetraptera* (0.9 ± 0.8 stems/ha) exhibited the lowest densities. Population densities decreased with increasing distance from the village. Starting from the village, the highest densities were found in transects 1 to 8, the first five of which are located in the Community Forest. The remaining eight transects, located mostly in Logging Zone, had relatively low densities of NTFP species. *Baillonella toxisperma* (found in six of the transect) and *Scorodophloeus zenkeri* (found in ten of the transect) had the lowest frequencies of occurrence (Table 1).

The general trend in size-class distribution for all the eight species showed greater numbers of young individuals, and smaller numbers of large diameter trees (Table 2). The highest density of regenerating trees (DBH < 5 cm) was found for *Afrostyrax lepidophyllus* (30.8 stems/ha), followed by *Ricinodendron heudelotii* (9.1 stems/ha) and *Pentaclethra macrophylla* (8.6 stems/ha). For *Afrostyrax lepidophyllus* and *Scorodophloeus zenkeri*, young individuals with DBH < 5 cm accounted for more than 90.0% of the total number of individuals. This ratio was close 87.6% for *Ricinodendron heudelotii*, 76.0% for *Pentaclethra macrophylla*, 54.5% for *Baillonella toxisperma*, 54.0% for *Irvingia gabonensis*, 39.6% for *Tetrapleura tetraptera* and 23.6% for *Panda oleosa*. This general inverted “J” curve of tree distribution is indicative of ongoing regeneration of these species. However,

**Table 1.** Density of the eight species in each transects and its difference among the species

| Species | Density for each transect (stems/ha) | | | | | | | | | | | | | | | | Mean density (stems/ha) | ANOVA* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | T11 | T12 | T13 | T 14 | T15 | T16 | | |
| *Afrostyrax lepidophyllus* | 38.3 | 76.8 | 46.7 | 47.9 | 19.0 | 53.9 | 67.1 | 76.2 | 12.3 | 22.2 | 4.6 | 6.4 | 12.0 | 12.4 | 2.7 | 13.6 | 32.0 ± 26.1 | a |
| *Baillonella toxisperma* | 0.0 | 0.2 | 0.0 | 0.2 | 0.0 | 0.4 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 ± 0.1 | d |
| *Irvingia gabonensis* | 6.6 | 1.8 | 4.3 | 2.2 | 1.1 | 2.6 | 2.4 | 1.9 | 1.7 | 2.2 | 1.4 | 0.8 | 1.0 | 0.2 | 0.4 | 0.5 | 1.9 ± 1.6 | cd |
| *Panda oleosa* | 2.0 | 4.0 | 2.6 | 2.6 | 2.2 | 1.7 | 2.9 | 2.0 | 3.5 | 3.7 | 2.2 | 0.9 | 1.2 | 1.0 | 0.6 | 1.2 | 2.1 ± 1.0 | cd |
| *Pentaclethra macrophylla* | 8.4 | 18.6 | 16.9 | 22.3 | 1.1 | 17.7 | 25.7 | 19.6 | 9.0 | 16.6 | 5.6 | 7.8 | 4.6 | 3.9 | 1.2 | 1.8 | 11.3 ± 8.2 | b |
| *Ricinodendron heudelotii* | 3.4 | 2.8 | 8.9 | 3.7 | 34.2 | 5.4 | 3.9 | 1.6 | 3.5 | 15.2 | 72.1 | 0.6 | 9.5 | 0.0 | 0.1 | 0.4 | 10.3 ± 18.5 | bc |
| *Scorodophloeus zenkeri* | 0.0 | 0.0 | 0.0 | 22.6 | 45.0 | 0.1 | 0.0 | 23.2 | 0.0 | 0.1 | 0.0 | 6.5 | 3.2 | 2.5 | 0.3 | 14.2 | 7.4 ± 12.8 | bcd |
| *Tetrapleura tetraptera* | 1.3 | 1.8 | 2.0 | 1.1 | 1.1 | 2.9 | 0.6 | 0.9 | 0.6 | 0.8 | 0.4 | 0.4 | 0.3 | 0.0 | 0.3 | 0.4 | 0.9 ± 0.8 | d |

*: Mean density values with same letter are not significantly different.

**Table 2.** Size- class distribution of the eight NTFP species populations

| Species | Tree density (stems/ha) | | | | |
|---|---|---|---|---|---|
| | DBH < 5 cm | 5–20 | 20–35 | 35–50 | DBH ≥ 50 cm |
| *Afrostyrax lepidophyllus* | 30.8 | 0.5 | 0.3 | 0.2 | 0.2 |
| *Baillonella toxisperma* | < 0.1 | 0.0 | < 0.1 | 0.0 | < 0.1 |
| *Irvingia gabonensis* | 1.1 | 0.3 | 0.2 | 0.1 | 0.3 |
| *Panda oleosa* | 0.5 | 0.4 | 0.6 | 0.5 | 0.2 |
| *Pentaclethra macrophylla* | 8.6 | 1.4 | 0.5 | 0.3 | 0.5 |
| *Ricinodendron heudelotii* | 9.1 | 0.1 | 0.1 | 0.1 | 0.9 |
| *Scorodophloeus zenkeri* | 6.7 | 0.2 | 0.3 | 0.2 | 0.1 |
| *Tetrapleura tetraptera* | 0.4 | 0.1 | 0.2 | 0.2 | 0.1 |

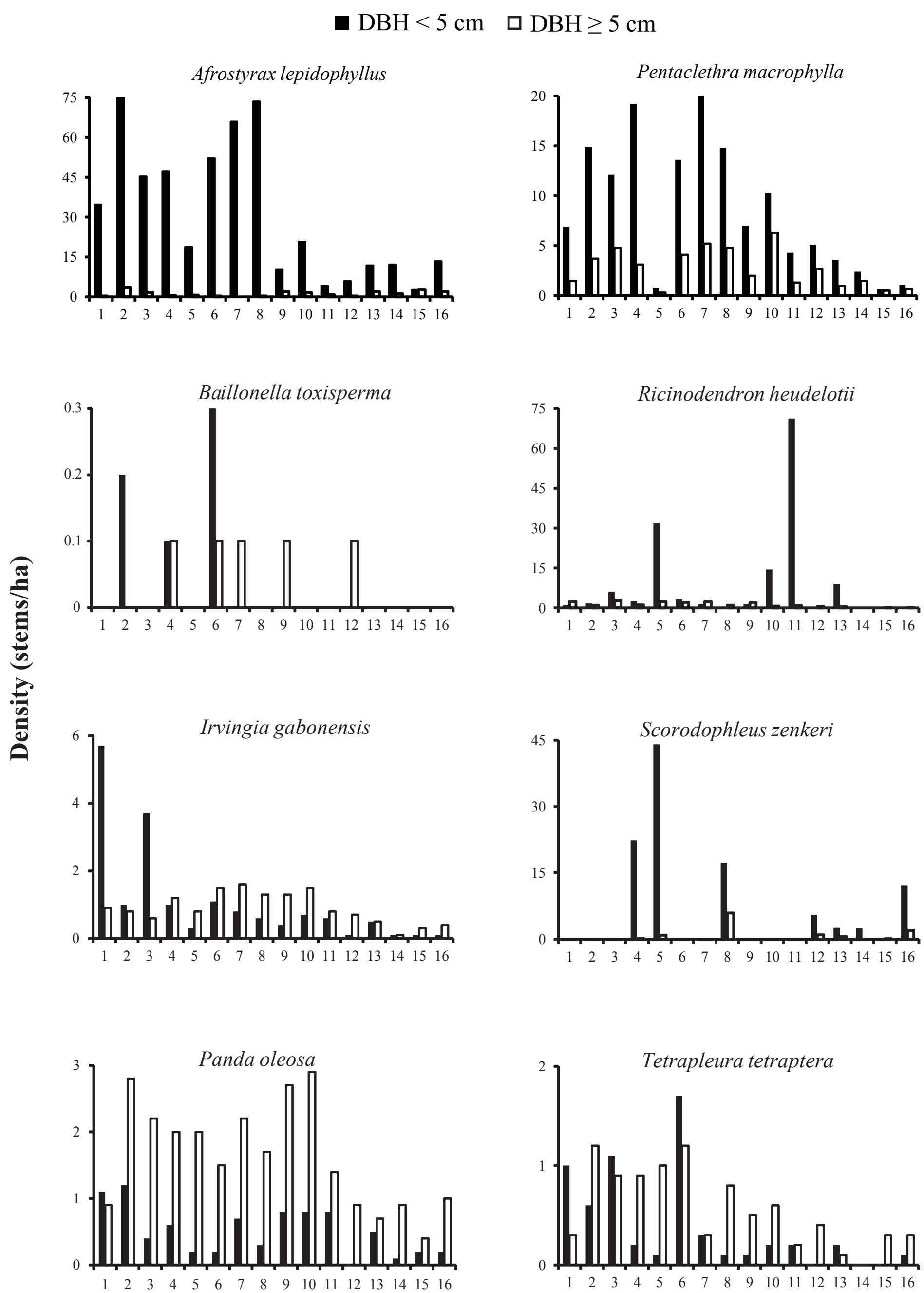


**Fig. 4.** Variation in the density of juveniles and adult individuals with varying distance from the village.

the lower densities of young individuals of *Baillonella toxisperma*, *Panda oleosa* and *Tetrapleura tetraptera* suggest that these species have slow rate regeneration.

As the 16 transects were laid out at 1 km intervals, this distance gradient was used to examine how the densities of seedlings, juveniles and adult trees varied with increasing distance from the village. *Afrostyrax lepidophyllus* and *Pentaclethra macrophylla* showed the greatest distributions of young individuals along this distance gradient. For all the species except *Ricinodendron heudelotii*, the densities of juveniles decreased with increasing distance from the village (Fig. 4). The density of young individuals of *Panda oleosa* was much lower than the density of adult trees (DBH > 5 cm). For *Ricinodendron heudelotii*, the density of adult trees remained constant along the distance gradient, while there was a general tendency for the densities of young individuals to increase with increasing distance from the village.

For trees with DBH < 5 cm, Spearman correlation analysis showed that the density-distance relationship was significant for *Afrostyrax lepidophyllus* (P = 0.004), *Irvingia gabonensis* (P = 0.005), *Panda oleosa* (P = 0.029), *Pentaclethra macrophylla* (P = 0.012) and *Tetrapleura tetraptera* (P = 0.014). The relationship was not significant for *Baillonella toxisperma*, *Ricinodendron heudelotii* and *Scorodophloeus zenkeri*. For trees with DBH ≥ 5 cm, this relationship was significant only for *Afrostyrax lepidophyllus* (P = 0.006), *Panda oleosa* (P = 0.033), *Ricinodendron heudelotii* (P = 0.0002) and *Tetrapleura tetraptera* (P = 0.004).

II. Natural Regeneration Status/potential

During inventories, seedlings and saplings of all eight species were observed. The NRI values were greatest for *Afrostyrax lepidophyllus*, *Scorodophloeus zenkeri*, *Ricinodendron heudelotii* and *Pentaclethra macrophylla*. These species are in an active regeneration process in the Gribe forest, as shown by their NRI > 1. In contrast, low NRI values were recorded for *Panda oleosa*, *Tetrapleura tetraptera*, *Irvingia gabonensis* and *Baillonella toxisperma*. This result is either due to their poor seeding, poor regeneration or differences in regeneration ability from the aforementioned six species (Fig. 5).

There was a general tendency for NRI values to decrease with increasing distance from the village. The values increased up to a certain distance (7 km for *Afrostyrax lepidophyllus*, *Pentaclethra macrophylla* and *Panda oleosa*; 5 km for *Scorodophloeus zenkeri*; 11 km for *Ricinodendron heudelotii*) and then started decreasing. For *Irvingia gabonensis*, *Panda oleosa* and *Tetrapleura tetraptera*, the trend was strictly decreasing (Fig. 6). Natural regeneration of *Baillonella toxisperma* was very rare and young and adult trees were scattered in the forest along the distance gradient. The Spearman correlation analysis shows that this distance-NRI relationship was significant only for *Irvingia gabonensis* (P = 0.023) and *Pentaclethra macrophylla* (P = 0.004).

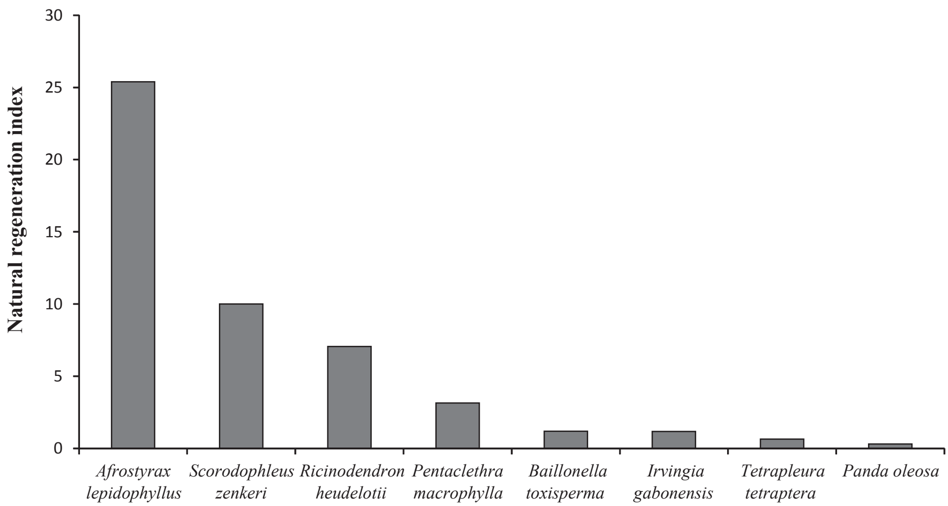


**Fig. 5.** Natural regeneration index of the eight NTFP species.

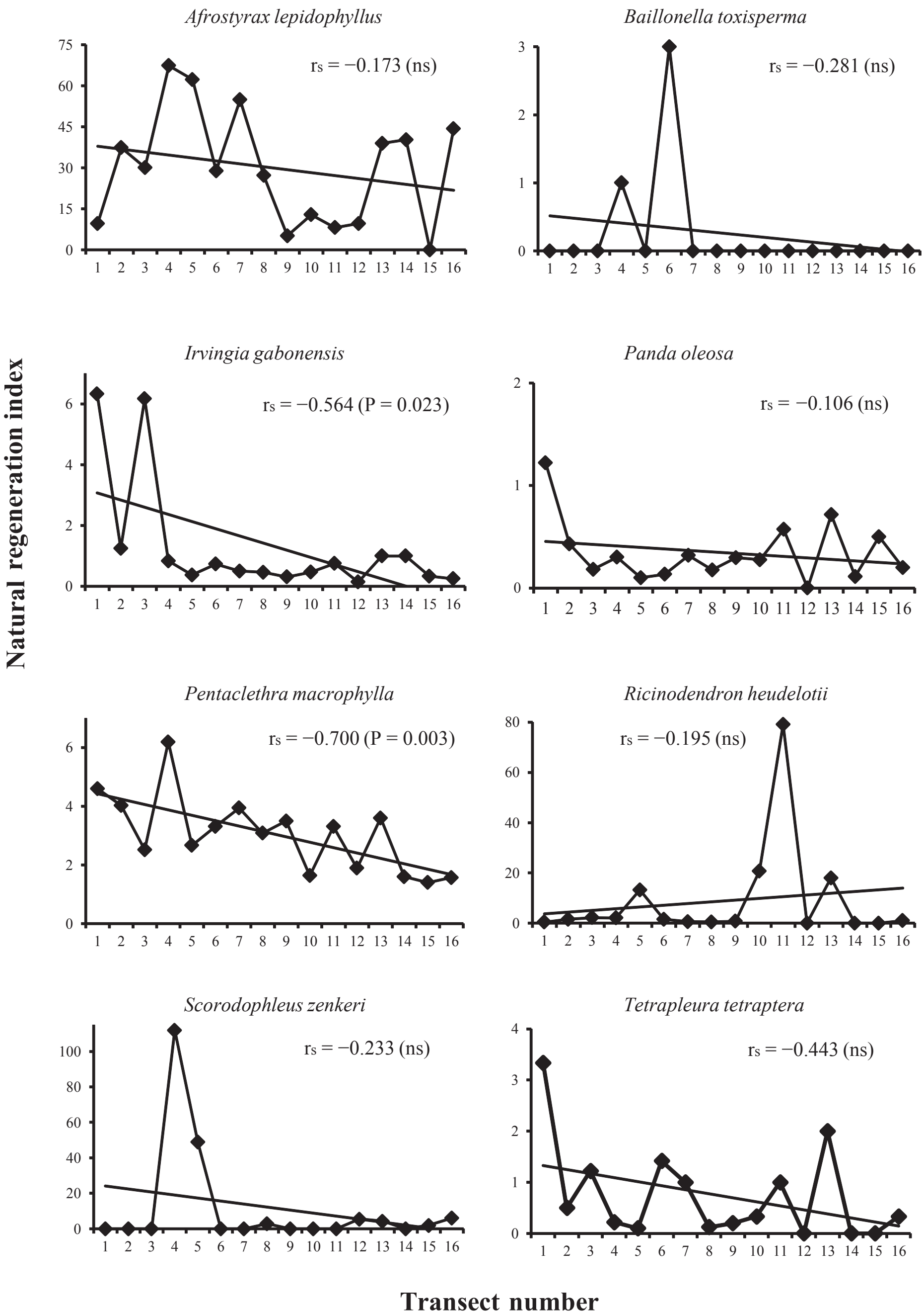


**Fig. 6.** Natural regeneration index variation with increasing distance from the village.

## DISCUSSION

### I. Species Density

The results showed that density values for *Afrostyrax lepidophyllus* (32.3 ± 26.1 stems/ha) were higher than those obtained from other studies using similar methodologies. Fokou-Sakam (2008) reported 7.2 stems/ha in the Lomié forest (East Cameroon), Nkongmeneck (1999) found 2.2 stems/ha in Nki National Park and Yasuoka (2009) showed that it was among the second most numerous species in the Zoulabot old-growth forest. The low density of *Baillonella toxisperma* (0.1 ± 0.1 stems/ha) confirms most prior NTFP assessments: 0.8 stems/ha in Lomié forest (Fokou-Sakam, 2008) and 0.3 stems/ha in the Kom-Mengamé Forest Complex in South Cameroon (Fongnzossie et al., 2010). Greater values were reported by Zapfack & Ngobo (2001a) in the Djoum forest in South Cameroon (2.3 stems/ha). The density of *Irvingia gabonensis* (1.9 ± 1.6 stems/ha) was close to the values obtained by Fokou-Sakam (2008) in Lomié forest (2.5 stems/ha) and by Fongnzossie et al. (2010) in the Kom-Mengamé forest (1.8 stems/ha). However, lower values were obtained in Djoum forest (0.8 stems/ha) by Zapfack & Ngobo (2001a), in Nki National Park in southeastern Cameroon (0.7 stems/ha) and in Boumba-Bek National Park (0.4 stems/ha) by Nkongmeneck (1999). For *Panda oleosa*, the density values (1.9 ± 1.2 stems/ha) are similar to those obtained in the Kom-Mengamé forest (2.8 stems/ha) by Fongnzossie et al. (2010) and in Boumba-Bek National Park (2.8 stems/ha) by Nkongmeneck (1999). Lower values (0.3 stems/ha) were reported in Djoum forest (Zapfack & Ngobo, 2001a). Yasuoka (2009) also found that this species was among the top ten ecologically most important in the Zoulabot old-growth forest. The density of *Pentaclethra macrophylla* (11.1 ± 8.2 stems/ha) was found to be higher than that reported in other areas of Cameroon: 2.0 stems/ha in Nki National Park (Nkongmeneck, 1999) and 4.3 stems/ha in Djoum forest (Zapfack & Ngobo, 2001a). The study area had greater numbers of *Ricinodendron heudelotii* (10.3 ± 18.5 stems/ha) compared to Lomié forest (1.3 stems/ha) (Fokou-Sakam, 2008), Boumba-Bek National Park (1.5 stems/ha) (Nkongmeneck, 1999) and the Djoum forest (3.4 stems/ha) (Zapfack & Ngobo, 2001a). For *Scorodophloeus zenkeri*, the density in the study area (7.4 ± 12.8 stems/ha) is lower than those obtained in Nki National Park (29.1 stems/ha) and in Boumba-Bek National Park (15.4 stems/ha) (Nkongmeneck, 1999). The density of *Tetrapleura tetraptera* in the present study (0.9 ± 0.8 stems/ha) is lower than the value of 5.4 stems/ha obtained in the Tikar plain by Zapfack & Ngobo (2001b).

Within the study area, NTFP species growing stock decreased with increasing distance from the village. The best potential harvesting zone lies within 8 km of the village. Beyond this distance, evidence of agricultural activities is rare and the NTFP species densities were greatly reduced, probably as a result of logging and associated activities (tree cutting, road opening, damage caused by felling trees, etc.) that have taken place in recent years. Similar observations were made at the periphery of the Dja Biosphere Reserve, where logging and the intensification of commercial hunting were reported to cause a reduction in the availability of wild fruits, such as *Baillonella toxisperma*, for local people and large mammals (Betti, 2004).

Vermeulen & Doucet (2004) calculated the number of tree stands needed to meet the demands of the local Badjoue community (about 300 members) living at the border of the Dja Biosphere Reserve. They concluded that it was necessary for these community members to have 26 fructifying *Irvingia gabonensis* trees, 17 *Baillonella toxisperma*, 7 *Ricinodendron heudelotii* and 71 *Trichoscypha* spp. These figures should be doubled in case of the Gribe community, which has approximately 700 inhabitants. Therefore, the growing stock of *Baillonella toxisperma* in the Gribe forest is not sufficient to meet the expected demand of the local population. For species such as *Afrostyrax lepidophyllus*, *Pentaclethra macrophylla*, *Ricinodendron heudelotii* and *Scorodophloeus zenkeri*, high population densities should support the commercialization of NTFPs, which could improve the local economy. Also, because the gathering of NTFPs considered to be ecologically less destructive than clear felling for timber, *Irvingia gabonensis*, *Panda oleosa* and *Tetrapleura tetraptera*, though having relatively low densities, can still serve as an important source of income provided they have a high fruiting efficiency.

## II. Ecology of Natural Regeneration

Recruitment of viable seeds, their germination, seedling establishment and initial seedling growth can be indicators of the regeneration status of a plant community. The processes involved in tree regeneration can be influenced by disturbance regimes and other factors, such as predation, canopy openness, soil moisture availability, as well as biological features of the species, such as their life cycles and behavior. The populations of the investigated species had numerous seedlings, except for *Baillonella toxisperma*, *Irvingia gabonensis*, *Panda oleosa* and *Tetrapleura tetraptera*. The very low seedling density of *Baillonella toxisperma* can be attributed to the low density of seed trees, which was caused by excessive selective logging of this species for commercial purposes. Other factors, such as environmental gradient (typically annual rainfall), as well as species-specific regeneration patterns together with disturbance regimes contributed to the low density of this species. For *Irvingia gabonensis*, population numbers have been reported to be declining due to logging operations, the expansion of human settlements and poor natural regeneration (World Conservation Monitoring Centre, 1998). Beaune et al. (2012) also reported a high mortality for *Irvingia* seeds and recruits in forests in the Democratic Republic of the Congo, with seed losses of 54% attributed to predation and 46% to pathogens and seedling losses of 100% due to predation and pathogens. These authors also highlighted density-dependent effects, also named the Janzen-Connell effects, where the mortality of seeds, eggs or other immobile organisms is correlated with their density. A few months after fruiting, a high abundance of seeds and seedlings can be found under seed trees of this species, but they do not survive for long period. *Panda oleosa* seeds are known to germinate slowly, starting after 10 months to 4 years (Lemmens, 2007). One of the major problems facing *Tetrapleura tetraptera* is the threat of extinction caused by deforestation and forest degradation. In addition, studies in Nigeria show that the fruiting efficiency of this specie (0.05%) is very low (Omokhua & Ukoimah, 2008).

The presence of abundant seedlings of the other species (*Afrostyrax lepidophyllus*, *Pentaclethra macrophylla*, *Ricinodendron heudelotii* and *Scorodophloeus zenkeri*) is consistent with a previous report from tropical rainforests (Whitmore, 1996). Their population structures, characterized by sufficient numbers of seedlings, saplings and adults, indicate that they are regenerating successfully. For *Afrostyrax lepidophyllus* and *Pentaclethra macrophylla*, their superior natural regeneration can be linked to their good fruiting efficiency and germination capacity. In addition, the high fruit predation of *Afrostyrax lepidophyllus* by small mammals ensures the dissemination of seeds throughout the forest. *Pentaclethra macrophylla* has fruits that explode at maturity, scattering seeds at great distances from seed tree, which reduces the density-dependent mortality that occurs when too many seeds germinate at the same time under a seed tree. The helophyte *Ricinodendron heudelotii*, is a gap opportunist and fast-growing pioneer tree (Plenderleith, 2000) that regenerates rapidly in open canopy forest and very poorly under closed canopies. Its high regeneration observed in this study can be attributed to the high degree of disturbances in the forest. *Scorodophloeus zenkeri* is a Caesalpiniaceae, a shade-tolerant tree species characteristic of evergreen forest. Its highly clustered population can be attributed to its efficiency in producing dehiscent fruits that open at maturity, thereby liberating numerous light seeds that are dispersed by wind throughout the surroundings of the seed tree.

Clearly, many factors may be responsible for the poor regeneration of NTFP species. The relative contribution of fruit gathering by the local population to the low frequency of small size-classes is not yet known. Research into the various factors that influence regeneration, as well as the development of demographic models that enable the prediction of population trends based on the current population structures, is needed.

## III. Management Implications

The findings from this study reveal that the NTFP species *Baillonella toxisperma*, *Irvingia gabonensis*, *Panda oleosa* and *Tetrapleura tetraptera* are a priority for conservation or assisted natural regeneration in the Gribe forest because of their low densities and poor regeneration rates. The threats faced by populations of these species are likely to be exacerbated by logging in the Community Forest and forest management units where local residents collect NTFPs. Although this study did not strictly address the influence of logging on the natural regeneration of the species, several studies indicate that logging directly affects species composition and growing stocks in forests ecosystems. In addition, studies of regeneration in African rainforests have demonstrated that without silvicultural treatments, natural succession in logging gaps may be insufficient for the re-establishment of tree species (Doucet et al., 2009). Because the Gribe forest still maintains high plant species richness and diversity (Tajeukem et al., 2014 this issue) and is a complex ecosystem, it is difficult to predict the impacts of logging on the forest ecosystem. In fact, our study area encompass several land management types (cultivated areas, Community Forest devoted to timber exploitation, logging concession and hunting zone) and much of this forest is covered by Community Forest and logging concession. However, it is also clear that the success of regeneration and the future condition of a logged forest is affected more by what is left than by what is cut from the stand. Thus, it is of critical importance to the future productivity of this forest that logging operators be knowledgeable of species requirements. For instance, special care should be taken to minimize damage to *Irvingia gabonensis*, *Panda oleosa* and *Tetrapleura tetraptera*. In addition, logging of *Baillonella toxisperma*, a multiple-use species whose timber is highly sought after by logging companies, must be stopped in light of the recent regulatory measures taken by the Ministry of Forests and Wildlife. Because of timber exploitation and the poor regeneration capacities of these species, forest authorities should consider revising the regeneration tax (which is currently 10 FCFA/kg for all NTFP species) to make it proportional to the current ecological threats faced by each species.

In addition to the problems posed by logging, field evidence has reported considerable changes in the fruiting occurrence of commercial NTFP trees with high potentials for income generation, such as the ones studied in this research. This has been attributed to climatic variations by most researchers. During many of our investigations in rainforest communities of Cameroon, fruiting occurrence of most NTFPs trees are unceasingly reported as becoming irregular and unpredictable, which imposes new threats to the already precarious livelihoods of forest-dependent communities. The lack of indigenous knowledge and practices related to the regeneration process has made it difficult to address such challenges. Vegetative propagation techniques (cuttings, grafting, layering, etc.) have been developed to regenerate NTFP species, with the aim of producing plants with shorter life cycles (Jaenicke & Beniest, 2002; World Agroforestry Centre, 2011). The World Agroforestry Centre demonstrated that NTFP species, such as *Baillonella toxisperma* or *Irvingia gabonensis*, regenerated through these techniques start fruiting after 3–4 years. Empowering and engaging the local community to intensify land use via the domestication of NTFP species will be advantageous. In addition, exploring distribution pattern of benefits from forestry activities in the Community Forest could enable the development of a multiple-use forestry system, which includes NTFPs, timber and environmental services.

In this regard, recent strategies to reduce carbon emissions through avoided deforestation and forest degradation and enhancement of carbon stocks ($REDD^+$) have opened up new opportunities for integrated management of NTFPs and environmental services. Some recent experiences from the Amazon Basin are clear examples of potential ways to bolster the conservation and livelihood benefits of NTFPs by linking their management to emerging markets for environmental services (Duchelle, 2012). This study demonstrates the need for the development of integrated approaches for NTFP management in secondary forests where agroforests might be needed to maintain biodiversity and carbon stocks. Pilot $REDD^+$ projects will enable new models to be applied in the Congo Basin forests where most protected areas are threatened by poor management of their peripheries.

## CONCLUSION

A careful ecological assessment of NTFP species promotes products that are environmentally and economically sustainable. This study concludes that *Afrostyrax lepidophyllus*, *Pentaclethra macrophylla*, *Ricinodendron heudelotii* and *Scorodophloeus zenkeri* are successfully regenerating in the Gribe forest, as evidenced by the large number of seedlings in these populations. In contrast, *Baillonella toxisperma*, *Irvingia gabonensis*, *Panda oleosa* and *Tetrapleura tetraptera* exhibited low seedling populations. This low number of seedlings might be attributed to poor seeding of matured trees, seed and/or fruit predation, heavy logging for timber production and physical damage of seedlings and sapling during cuttings, etc. Natural regeneration alone will not be sufficient to maintain the desired growing stocks of these species, and immediate restoration measures should be taken to assist the natural regeneration process. Moreover, basic research into the regeneration process and the utilization of local peoples' knowledge and practices related to the regeneration and management of NTFP species are needed to develop better environmental management tools.

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